MOVES 2004: Where We Came From, Where We're Going

Michael Zyda, Director

The MOVES Academic Program

The MOVES degree program began in March 1996 with the approval of the master's in modeling, virtual environments, and simulation by the NPS academic council (the MOVES PhD was approved in March, 1999). The MOVES degree was designed as a pragmatic mix of computer science and operations analysis. We had a lot of sponsors coming in saying, we love the networked-visual-simulation work you're doing, the networked-virtual-environments work, but we would also like your students to graduate with an understanding of the combat-modeling courses offered by the operations research department at the Naval Postgraduate School. So we built this very pragmatic set of matrices for the two-year master's program.

MOVES has since evolved to become a field of its own. In fact, the MOVES degree is managed by a separate academic unit, an interdisciplinary academic committee chaired by Professor Rudy Darken.

So the question then is, why this unusual degree and what are we trying to achieve with that degree? Our students go on to manage M&S systems, not build them; we believe it important that they learn how to architect next-generation M&S systems. How can someone manage or architect a system without the fundamentals of what is being built? He can't.

Where do the institute's students come from? Well, MOVES defines the Navy's subspecialty in M&S, the 6202 P-code, for which the Navy has sixty-five billets. The Marine Corps has an M&S subspecialty as well, MOS 9625, with seven billets. For the US Army simulation-operations functional area FA-57 there are 450 billets requiring M&S professional education, and the army plans to quadruple that, is what we are hearing.

MOVES supports the international community as well. We have students from Turkey, Singapore, Greece, Germany, Bahrain, Tunisia, and Uzbekistan, among others. The campus as a whole matriculates students from fifty-six countries.

The past year saw a revision of the MOVES degree program. The MOVES master's program comprises a group of core classes supplemented by blocks that differentiate the degree for the individual student. In addition to the core, each student choses three (from a possible nine) specialty blocks, each block adding three courses to a core component. For example, the combat-modeling block adds advanced combat models, wargaming, and joint campaign analysis to the core's introductory combat-modeling class. Networked visual simulation, web-based simulation, agents and cognitive modeling, training systems, human factors, physically based modeling, optimization, and management and acquisition (which allows students to gain understanding of acquisition regulations and acquiring military systems using M&S) constitute the other blocks.

We tap into the NPS math and OR departments for mathematical fundamentals and coordinate with computer science for programming fundamentals. Our courses in objects and programming data structures, systems, and networks are a mix of CS and MOVES.

The MOVES Research Program

The mission of the MOVES Institute is research, application and education in the grand challenges of modeling, virtual environments, and simulation.

Our areas of focus are

- Web-based simulation
- Computer-generated autonomy and computational cognition
- Human-performance engineering and game-based simulation
- Combat modeling and analysis

Web-based simulation work starts with the premise that all future M&S systems will eventually become operational systems. Looking at what's going in DoD and the internet, it's clear that the internet is the best-integration medium for this future—and the work we're doing in web-based sim is key to the DoD's future in M&S.

Computer-generated autonomy concerns how to model human and organization behavior in the simulation system. Important work for the intelligence community goes on here as we probe the modeling of terrorist behaviors and asymmetrical warfare.

Human-performance engineering and game-based simulations are a real hot area for us. Our path at the MOVES Institute has gone from visual simulation to virtual reality to game-based simulation. Today everybody wants his next-generation combat modeling and training system to have a game-like interface. We've become the experts here at NPS, especially from our experience producing the very successful *America's Army* PC game, a game spun-off this year into an Army development organization. Human-performance engineering is how do we take the systems we build and then determine what levels of fidelity are required for effective training and what training we can actually do with the system produced.

In combat modeling and analysis, a lot of our work is taking existing combat modeling systems and bringing them into the institute for understanding and revision by our students, faculty, and staff and for building simulations that allow us to analyze what may or may not happen in an area of interest.

Our organization is that of director and technical directorate. I am director of the MOVES Institute; in the technical directorate, John Hiles heads computer-generated autonomy and computational cognition, Don Brutzman directs web-based simulation, and Rudy Darken leads human-performance engineering and game-based simulation. We share Ted Lewis with homeland security and defense, and LTC Tom Cioppa, who is the director of the U.S. Army's TRAC Monterey, provides guidance in combat modeling and analysis.

The MOVES advisory board brings together military, educational, and industrial leaders to provide guidance on funding for research and products. These very helpful people help us review what we've done in the last year and guide us in the direction we should go. See http://www.movesinstitute.org/advisoryboards.html.

MOVES represents sixty-eight faculty and staff; we are the largest interdisciplinary group on campus, paying faculty and staff from MOVES reimbursable totaling about $14,000,000 in fiscal 2004. We are working with approximately seventy students from the four NPS schools.

Good communications is one reason MOVES does well. We have regular meetings and mailing lists and events to get everyone to work together, including weekly meetings on research projects, agents and combat, HPE and game-based sim, and web-based sim, as well as our Thursday brown-bags, in which students present their current work. The directors also meet weekly. We run the MOVES participants'

mailing list, focus-group mailing list, and director's mailing list. Our biggest event is the annual MOVES open house, in which answer the question, what did MOVES do in the last year? We also produce an annual report and maintain a website. This is the annual report!

Web-Based Simulation

Technical Director – Dr. Don Brutzman

N81 MOVES began work with N81, the Navy's operations analysis organization, on a major initiative to create a new class of modeling and simulation capabilities, moving away from monolithic, closed system designs to open M&S frameworks that allow rapid integration of modular, loosely coupled components. The idea is to create agile analytical capabilities for the variety of missions conducted today; the pattern for success is the internet. MOVES researchers conducted software analysis, design, and development and investigated upgrading the existing code bases (SimKit and NSS) to integrate functional capabilities with the SimKit-based Combat XXI simulation.

XMSF XMSF (extensible modeling and simulation framework) is a set of Web-based technologies within an extensible framework that enables a new generation of modeling and simulation (M&S) applications to emerge and interoperate. This Defense Modeling and Simulation Office-initiated project asserts that Web services provide the best technical approach and business strategy for large-scale progress. The application of XMSF concepts to analytical modeling involves researching the development of a transformational analytical modeling framework where Web services and XML-based data interchange are used in an innovative way to connect multiple model components in a flexible, scalable, extensible architecture.

Key sources of functionality for these efforts include:

• SimKit discrete event simulation application program interface (API) developed by NPS Visiting Associate Professor Arnold Buss,

• Combat XXI under development by the Army and Marine Corps at the Army TRADOC Analysis Center (TRAC), White Sands, which uses SimKit as its core simulation engine,

• Naval Simulation System (NSS) developed by SPAWAR Systems Center, San Diego and managed by NAVAIR.

Following the strategic trajectory of the XMSF effort, this work starts first with functioning exemplars, progresses to supporting tools, and then steps up to world-class modeling challenges, analysis, and results. Shortly after I/ITSEC, NPS received funding from OPNAV N81 to complete the integration of these models and to demonstrate the integrated functionality in a number of FORCEnet-related analyses that require a comprehensive air, land, sea modeling

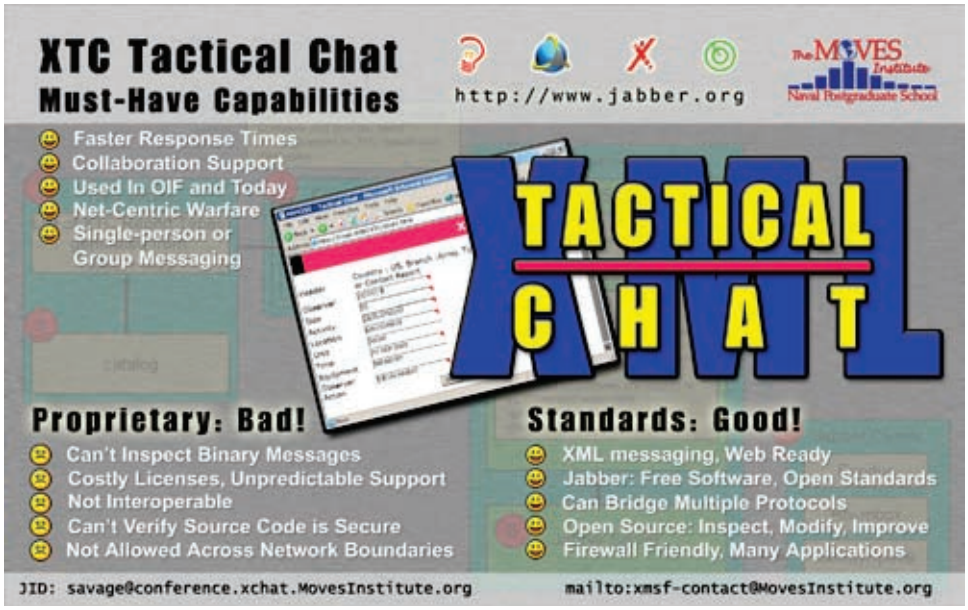
environment. As part of this effort, the MOVES Institute is developing an "analytical workbench" providing a user access to a collection of past and current SimKit models developed in student thesis projects over the past five years. These models will provide a library of analysis tools from which analysts may explore a wide range of problems and from which analysts can evolve customized models to address new problems of interest.

FAST FAST (flexible, asymmetric, simulation technologies) is developing an integrated set of simulations, databases, and computational tools for use by deployed military analysts facing challenges in military OOTW missions. NPS is working with the FAST government/contractor team to enhance capabilities for interchange of static-scenario definition data across the family of simulation models, using common vocabularies such as XML representations of the command-and-control information-exchange data model (C2IEDM) and battlespace management language (BML). MOVES thesis research is focusing on representation of combat-unit data and access to the unit order-of-battle data-access tool (UOB DAT) through Web services. Our XMSF partner Mark Pullen of George Mason University is employing the extensible BML (XBML) work toward a common command-and-control language for linking M&S systems with C4ISR systems.MOVES has coordinated internal technical performance of the task and supported contractor efforts in evaluating data-interchange issues and the integration of agent-based.

Naval Simulation System (NSS). MOVES is continuing efforts to promote application of NSS within NPS curricula and in support of naval analysis, coordinating with the Naval Modeling and Simulation Management Office, SPAWAR Systems Center (San Diego), the commander of the Pacific Fleet, and NAVAIR to manage the NSS code base and provide independent verification and validation of the software.

Analytical Modeling Framework (AFM). MOVES prepared the proposal and contracting paperwork to launch an analytical modeling framework project for OPNAV N81. Initial work supported preliminary design and development of the framework, involving integration of NSS with the NPS-developed Simkit discrete-event-simulation software library, employing XMSF concepts such as Web services.

Homeland Security MOVES has prepared proposals and has received funding for working with Homeland Security on integration of an operational-planning system developed by Lawrence Livermore into the Homeland Security curriculum, bringing XML-based tactical chat capability into a naval-communications architecture proposed by NPS's Cebrowski Institute. MOVES is also involved with a collection of OPNAV N81 projects relating to development and application of an advanced analytical-modeling capability.



Deformable Surfaces (or, distributed real-time destruction of building models using ultra-high resolution building format and X3D). MOVES is working with the TRADOC Analysis Center, Monterey and the army's Engineer Research and Development Center to develop a standard representation of 3D structures for the OneSAF objective system (OOS). A vocabulary for describing the structures has been designed as an XML schema, enabling software to self-validate user, tool, and software-generated files describing building structures. XML stylesheet language transformation is used to transform the building descriptions into X3D (extensible 3D) graphic representations of the structures for rendering in the Yumetech Xj3D open-source implementation of the X3D-language standard. Physics models are applied to modify the XML representation of the buildings to simulate ordnance effects.

Online Mentors for Language Training and Cultural Familiarization The MOVES Institute is working with Vcom3D and the Defense Language Institute to develop an interactive, online instructional aid presenting real-world situations to motivate students in language acquisition and cultural familiarization. Vcom3D has developed an initial prototype implementing a short scenario involving a military roadblock in Iraq. The user interacts with the scenario to make decisions informed by language usage and cultural cues. Ongoing work will further develop the prototype for learning-effectiveness studies in 2004.

SAVAGE SAVAGE (scenario-authoring and visualization for advanced graphical environments) is an library of dynamic 3D models and authoring tools using X3D graphics, developed by faculty, students, and contract support over the past 3 years. Now numbering 857 models in 21 categories (e.g., biologics, scenarios, and ground vehicles), the SAVAGE archive provides instantly available components for on-the-fly rendering.

Web-based Technologies for Analytical Combat Modeling In addition to efforts towards common vocabularies for data interchange, MOVES demonstrated the ability to use the XML expression of scenario data from the FAST models to initialize a multi-agent simulation constructed with the MOVES agent framework by researchers under John Hiles. Through an open and common-data interchange, arbitrary models can readily tie into the information for specialized studies.

Anti-Terrorism / Force Protection (AT/FP) Planning Tool Recent MOVES thesis research employed the MOVES agent-based simulation constructs and the Xj3D open-source implementation of the emerging X3D web-based graphics standard to model small-boat surface threats against ships in port. Inspired by the USS *Cole* bombing in Aden Harbor, the tool allows force-protection planners to visualize a port in 3D and to run analyses on the placement and capabilities of picket boats for protection of naval shipping from attacks by small boats. Aden Harbor, Port Hueneme, and Pearl Harbor are currently available in the tool for visualization and analysis. Recently received tasking from OPNAV N81 will extend the capabilities of the model to examine additional threats and protection measures.

Web-based 3D Visualization of Tactical Databases and Digital Terrain for Operational Planning Over the past year, a number of students completed XMSF-related research for their thesis projects, including auto-generation of XML schema descriptions of the Digital Terrain Elevation Data (DTED) specification to create XML representations of DTED data files. Once the data is in an XML representation, XSLT is used to transform terrain-elevation data to other forms, such as X3D, for rendering. This work provides a basis for rapid generation of 3D terrain for simulation and planning systems. Other research involved added terrain-following algorithms to this work so that objects moving over the terrain enjoy correct orientation. Together, these efforts contributed to Web-based visualization of the 3D battlespace in a July 2003 demonstration for the Joint Forces Command (JFCOM) Distributed Continuous Experimentation Environment (DCEE).

Similar thesis work in open-standards, Web-based visualization techniques added the ability to query military databases to place information icons dynamically in 3D space (consisting of terrain elevation data with map overlay). The user flies through the 3D environment by joystick and requests detailed information on objects in the environment by clicking their icons. For example, the user can request information on airfields, generate a 3D representation, and fly over the terrain, selecting particular airfield icons to obtain details (e.g., latitude and longitude). All information exchanged between the user and the database server, as well as the resulting representation of the battlespace, is XML-based, providing self-validating and self-describing data within a simple software implementation.

Sonar Visualization for Multi-Platform Net-Centric Undersea Warfare The MOVES Institute is conducting research with Sonalysts, Inc. to represent and visualize sonar propagation and performance for use in antisubmarine warfare and autonomous underwater vehicle (AUV) research. In preliminary work, Yumetech, Inc. implemented recursive ray acoustics algorithms in the Xj3D software environment for visualizations demonstrated at I/ITSEC. This work is ongoing through a Phase II small-business innovative research award to Sonalysts. NPS and Sonalysts are currently establishing a cooperative research and development agreement for continuing efforts in 2004.

Autonomous Underwater Vehicle (AUV) Workbench The MOVES Institute is a major contributor to AUV robotics research at NPS. Theses in 2003 defined an XML-based command language for an AUV, providing unambiguous and self-validating structure and content of mission plans. The MOVES Institute has developed an AUV workbench, enabling the user to plan AUV missions and visually execute the mission to ensure the plan is defined as desired. Mission execution applies physically based models of the vehicle dynamics for realistic performance of the AUV in the assigned mission and ocean environment.

XML-based Tactical Chat At the same time that civilian use of instant messaging and internet chat has exploded over the past few years, the military has seen these communications evolve into a primary method for coordination in

shipboard operations. As freeform, unstructured interaction, however, these communications are difficult to analyze and log. The XML-based tactical chat (XTC) effort started as a student project in an advanced XML class, with the idea that providing structure to chat exchanges through XML representations shold provide great operational and analytical benefits. A tactical chat environment has been created as a basis for ongoing research into this medium.

Computer-generated Autonomy

Director: Professor John Hiles

In autonomy and cognition, MOVES has produced a software library that simplifies the development of software for identifying and anticipating the intent of a subject or contact and is creating computational analogs, using software agents, of the backstage cognitive operations now being mapped out at universities around the world. Our work has explored the nature of compound multi-agent systems and has started engineering work to make it possible and practical to build such systems in software.

The formalized architecture for cognitive blending (CB) in agents has been defined, documented, and implemented by extensions to the CMAS library (compound multiagent system library). This component will be used by later stage work within this project and by other research projects and student projects at MOVES and NPS.

Our architecture for CB produces fast and parallel blending that can be harnessed inside Compound Multiagent Systems. One master's thesis and other research projects have already used preliminary versions of the architecture (and CMAS Library). They demonstrate a substantial increase in development speed, compared to attempting to hand code the demanding project of placing agents within agents. One student reported that after spending weeks trying to hand code his CMAS application and not getting a good result, he started over with the preliminary version of the library and got a working application within a few days.

Two remaining tasks will expand the support for single-scope blending (SSB) from within the CMAS library (along with documentation for building SSB support with library services) and build a demonstration based on those library services. We will illustrate the flexibility this brings to the software, especially for applications that assess and react to events happening in their virtual world. The demonstration program will be the subject of our summary report on the project and will help with insights into the new capabilities of compound agents and multiagent systems that are equipped with computational cognitive blending.

Currently underway are IAGO, the operations-other-than-war (OOTW) toolbox, Red Team Intent, single-scope blending, and Protean Media, projects that are based in and attempt to fuse multi-agent coordination techniques from biology and biochemistry, cognitive blending, and compound multi-agent systems.

IAGO As a first phase to the Iago project, MOVES is exploring the use of computation to mimic the characteristic ways a subject makes sense (or creates meaning) from a problematical situation. For this study, a stream consisting of sequential events from a subject's life was created and formatted for use with the computational-blending model.

OOTW Toolkit and MACS (modeling adapted cognitive subjects) – These projects look at techniques for connecting cognitive models, such as Iago, with traditional models and simulations. The hope is to enhance traditional models, consisting entirely of simulation objects, by adding subjective interiors that would provide insight into what events in a simulation might mean to someone actually present in the simulation.

The first phase CMAS Library was completed as part of another MOVES research project (OOTW Tool Kit). Building on that library and on the XML-based interchange protocol used in the Tool Kit, we have reached intermediate results:

- Research projects and thesis work have been built that demonstrate CB at work within applications that use the XML-based input streams to learn about their surrounding environments. Cognitive blending, within the agents, construct mental spaces (which we implement as tickets) that recognize external events and combine the information that they contain with other constructs to create knowledge about emerging patterns. This knowledge – derived from the blending of incoming XML sensory streams – in turn drives the behavior and choices of the Compound agent.

- The XML sensory stream format has been added to a Problem Simulation that was part of another MOVES research project. This simulator is Protean Media, which is part of a project funded by NPS, and several intelligence agencies. The Protean Media wargame are designed to be flexible and easy to change to other subjects. The version we are working with deals with politico-military policy and decisions in contemporary Iraq.

We are on track to complete this project by building a compound agent that will plug into the XML sensory stream from inside Protean Media. Our agent will use CB to detect, identify by type, assess, and summarize events in the problem simulation. The Probe agent inside the problem simulation will send its assessments and summaries to the war game's participants during play.

Our project report will describe these results and include output from test runs of the problem simulation.

Red Team Intent (RTI) RTI comprises a series of projects in agent-based modeling of intent. The focus is on studying the apparent intent of a given contact who is under observation by air, sea, or land surveillance and of the intentions of entities in a surveyed database. The question is whether computation can be used to provide a focus-of-attention system within a larger surveillance system. Cognitive blending and other techniques from Iago are also extended via this project.

Single-Scope Blending – This project aims to extend the computational methods first developed in Iago and later extended in the RTI projects to include a more symbolic form of cognitive blending, called single-scope. A successful outcome will permit cognitive systems to make more extensive use of symbols in compressing knowledge and increase the flexibility of expanding knowledge in order to apply it to problem solving.

Protean Media The name of this project comes from *Proteus: Insights from 2020,* an NGO-sponsored book that investigates new methodologies and technologies for intelligence collection and analysis. Protean Media is a computer-assisted politico-military wargame designed as a sort of "cloud chamber": a means of helping people think differently about decision-making under political and military uncertainty and to see forces that might bring unintended consequences to their actions. The setting of Protean Media's first version is contemporary Iraq.

Another area of research under this directorate is Chris Darken's work in developing a context-driven architecture for natural-language processing, based on a deep understanding of the context of the utterance, (i.e., events and processes at work in the agent's environment), MOVES uncovered obstacles to representation of context for software agents in military simulations and developed methods of exploiting computer-graphics techniques for modeling the inter-visibility of battlefield

entities in 3D simulations. A methodology for exploiting the class of mental simulations that are metaphorical (e.g., modeling the movement of multi-entity forces as the movement of a fluid or gas) and a general model of mental simulation are currently in development, supported by a follow-on grant. The building of computational models of embodied cognition is also a funded work in progress.

Artificial Eyes and Skin: A Computational Perception Testbed —Starting from our previous work (Darken 2004), we have been working on the raster-based approach to modeling visual perception and specifically target acquisition described in that work. In this approach, the agent is presented with information about the environment (a pixel raster) that is similar to what a human user receives through a graphical interface. This approach is the first to have the potential to realistically account for such factors as shadow, camouflage, silhouetting, and smoke in real time. We have designed a set of algorithms for this purpose and are implementing them to run on consumer graphics boards to allow real-time performance.

We have also developed a representation of tactile sensation that has been ready for several months, but implementation on the target platform (the open-source dynamics engine ODE) has not been possible due to unforeseen limitations of the early version of the platform that was available. These limitations have been removed in the latest release of the platform, and the way is clear for further progress.

Human-performance Engineering and Game-based Simulation

Director: Professor Rudy Darken

NETC Virtual Ship The Naval Education and Training Command (NETC) asked us to build a virtual ship to demonstrate the capability of game-based simulations in training sailors, to be demonstrated at the Interservice/Industry Simulation and Education Conference. For this short-fused (seven-week) assignment, we visited an AEGIS destroyer in San Diego, created a plausible and workable scenario to train sailors, built a model from scratch, and created the first application using the MOVES' new simulation engine, P-51. Our successful project was chosen for presentation to VADM Al Harms, commander of NETC, and received written commendation. We anticipate a major research grant in FY-04 to create the basis for future training simulations. NETC has informed us that the CNO will be briefed on the possibility of a NETC/MOVES partnership.

Game Building The MOVES Institute continued to improve and expand the award-winning *America's Army* PC game in 2003. Or as GameSpot put it, "Originally released last year, *America's Army* evolved dramatically in 2003. It's still a top-of-the-line, highly challenging, realistic shooter."

- We released ten versions of the game, including Mac and Linux versions
- Twelve new missions were added: radio tower, weapons cache (second edition [SE]), bridge SE, AVWID weapons training, escape and evade, mountain pass SE, Special Forces combat search-and-rescue, Special Forces reconnaissance, Special Forces hospital, Special Forces pipeline, and Special Forces sandstorm
- New weaponry and equipment included the customizable M4A1, AT4 anti-vehicle weapon, RPG7 rocket-propelled grenade, incendiary grenade, M9 pistol, Vintorez rifle, and the Stryker personnel carrier.
- New occupations were combat medics, engineers, and scouts - RSTA/UAV.
- Registered users during this period climbed to nearly 3M, at an average rate of 175K new users each month.
- Awards include Gamespy's 2003 Game of the Year Awards, "Best Value," Gamespot's Best Multiplayer Game of 2003 (finalist), DoubleClick's Insider's Award, Best Multi-Channel Marketing Campaign (honorable mention), Action Vault's Debut Game of the Year, Action Vault's Surprise of the Year,
- The game was featured at San Francisco's

Yerba Buena Art Center, for which MOVES edited and produced a beautifully illustrated show catalog, now in the Library of Congress.

The Army has decided to spin off *AA*, thus closing a profitable and exciting chapter in the game's career, namely, its conception and coming-of-age at MOVES (3M+ registered players).

Delta 3D Game Engine Our experience with *AA* lead to a proliferation of requests for game-based training simulations. In response to the problem that game engines are typically too expensive for government budgets, MOVES is developing a full-featured open-source game engine, called Delta3D Open-Source Game-Based Simulation Engine (recently renamed from the P-51 Engine), for use in DoD and DHS training and education programs.

We began discussions in November 2003 with NETC with regard to delivering game-based simulations as part of a variety of training and educational courses. It appears at this time as though NETC intends to build training and education games using our engine, possibly starting in FY05.

The initial prototype toolkit was built on the Gizmo scene graph, which had a free license but not open source. We now use Open Scene Graph and Open Dynamics Engine for physics, Cal3D for character animation, and TinyXML for XML reading and writing. We use several more open source modules, taking a "best of breed" approach to selecting modules. We are concerned about community and want to provide a unifying tool that members of all these open source communities might find useful. This strategy gives us the best flexibility and opportunity for success. The more developers (i.e. the larger the community), the more stable the software, the better suited to our purpose. The development project has been moved to Sourceforge and is already available for use.

We anticipate the first official release at I/ITSEC 2004 with pre-release happening concurrent with the MOVES Institute Open House in August. FY04 accomplishments include:

- Completed the port to Open Scene Graph
- Incorporated audio using OpenAL
- Added DIS/HLA networking
- Included a set of representative input and output devices
- Basic Linux compatibility
- Linked to contemporary combat modeling systems (i.e. JSAF)
- Added collision detection and physics
- This project has also supported many MOVES theses. Weekly Delta3D development meetings are attended by up to 10 MOVES and CS thesis students. This is the most active project with students in the Institute.

Improved Chromakey-Based Augmented Reality Training System

Beginning in FY03, the MOVES Institute began work on developing a new system for deployable training we called the Chromakey Augmented Virtual Environment (or ChrAVE). This was used in an ONR sponsored program for our virtual environment helicopter (VEHELO) apparatus. We completed several configurations of VEHELO, only one of which was the ChrAVE, but this approach held such promise as an exciting way to immerse the trainee in a natural environment (the actual vehicle cockpit used for operations) that it was funded for specific development and experimentation. The first implementation of the ChrAVE consisted of standard chromakey materials, We used blue-screen fabric with high quality fluorescent lighting and a high quality camera mounted to a head-mounted display.

This worked relatively well but it was difficult to manage lighting effectively. The blue-screen material was very sensitive to lighting, so much

so that we often had problems with parts of our image "washing out," because we did not have a consistent level of lighting across the surface of the material. Our proposed solution to this problem, funded in FY04, was to experiment with a new technology called the LiteRing, a ring of colored lights that surround the camera lens. We replace the blue screen material with a highly reflective material similar to that used in standard projection screens. Because the camera is still attached to the wearer's head, wherever the wearer looks, that area is lit with blue light. The same principles then apply. The same mixer is again used and the virtual environment replaces the view outside the cockpit.

In addition to improved lighting consistent

Improved chromakey-based augmented-reality training system

across the surface of the material, we were also able to better control the lighting qualities inside the aircraft for NVG operations. We had a problem previously in that the cockpit always had to be fully lit for the ChrAVE to work. Even when we simulated NVGs, the outside environment looked reasonably correct, but inside the cockpit everything was very bright as if it were daytime. Using this technique we are able to keep the light levels inside the cockpit to low light which helps immerse the pilot in the simulation.

This apparatus will be used again this year as we develop a prototype combined arms training system combining our previous work with Forward Observers with the ChrAVE for helicopters simulation as part of our ONR sponsored research.

Inertial/Magnetic Sourceless Motion Tracking for VE—Accomplishments in FY04 can be divided into four categories: development and fabrication of hardware for a full body-tracking system, design and implementation of real-time software to support the body tracking system, design of a human avatar for use in networked virtual environments, and experiments to evaluate the overall accuracy and robustness of orientation estimates using inertial/magnetic sensors when under the influence of variable magnetic fields and design of a factored quaternion method for orientation estimation using MARG data.

In FY04, the fourth generation of the MARG sensors (MARG IV) were designed and fabricated. This sensor module achieved further form factor reduction through the use of a micromachined rate sensor. In addition, a software system capable of processing data from sixteen inertial/magnetic sensors at an update rate in excess of 100 Hz was implemented. A cartoon-type humanoid model, called Avatar Andy, was developed to meet the needs of the MARG project Gauss-Newton iteration has been shown to be an effective linearization means for

accomplishing either optimal or complementary filtering for real time orientation estimation from measurements of Earth gravity and Earth magnetic field.

The Natural Language Tutor We worked with Stanford's Center for Study of Language Information to build a natural-language tutor for a computer-based trainer intended for damage-control assistants on navy ships, and to create a simulation to maximize the training value of the system. Our objective was to develop a new architecture for natural language processing by software agents based on a relatively deep understanding of the context of the utterance, i.e. the focal events and significant ongoing processes at work in the environment of the agent.

Our work uncovered two key obstacles preventing adequate representation of context for software agents in military simulations: inadequate perceptual modeling (i.e. representing what parts of the environment are available for the agent to represent as context) and the lack of mental simulation algorithms that would allow agents to distinguish likely from unlikely interpretations. To address the most important aspect of the perceptual modeling deficit, we have developed a set of three methods exploiting computer graphics techniques for modeling the inter-visibility of battlefield entities in 3D simulations.

To address the mental simulation issue, we have developed a methodology to exploit the class of mental simulations that are based on the metaphoric reapplication of models of the physical world to battlefield phenomena (e.g. modeling the movement of multi-entity forces as the movement of a fluid or gas). This aspect of the work is still under active investigation. Secondly, we have developed an approach to learning context, modeled as the ability to predict future percepts. We have implemented a test-bed virtual environment and learning algorithm. This system has successfully learned the identification and consequences of up to 70,000 situations (contexts). It has achieved an average prediction ability of over 60% averaged over all percepts, including those that are irreducibly random and unpredictable.

ONR is providing funding to continue this project in FY-05.

XRTI The Extensible Run-Time Infrastructure (XRTI) is an open-source, freely redistributable, Java-based implementation of the IEEE 1516.1 high-level architecture interface specification. The aim of the XRTI project is to provide a foundation for research into improvements and extensions to the high-level architecture. The XRTI prototype implements a subset of the RTI interface and demonstrates the extended features of the XRTI.

We developed a prototype version of the XRTI in Java that acts as an RTI conforming to a subset of the IEEE 1516 HLA standard and demonstrates possible improvements to the standard: a proxy compiler system that automatically creates sets of easy-to-use, documented Java classes for arbitrary federation object models; a binary protocol for interoperability that uses the encodings defined in IEEE 1516; and a mechanism for dynamically extending the federation object model, allowing the seamless introduction of new classes of objects.
The XRTI prototype is available under the BSD open-source license from the project web site, www. nspnet.org/~npsnet/xrti.

To test the XRTI in an actual shared environment, we added support for XRTI networking into NPSNET-V, a component-based dynamically extensible virtual environment architecture. In addition to testing the basic functionality and dynamic extension capability of the XRTI, we compared its performance to that of two commercial RTIs: the DMSO RTI-NG and the MAK RTI. The XRTI's performance matched or exceeded that of the commercial RTIs in terms of all metrics measured: the latency of communication, the amount of bandwidth used, and the amount of CPU time required.

Virtual Vaudeville In another aspect of 3D visual simulation, MOVES is supplying the National Science Foundation's Virtual Vaudeville project with an interactive audience module. The Virtual Vaudeville system recreates, through computer-gaming and motion-capture technologies, the experience of attending a vaudeville performance at the turn of the century. MOVES' contribution governs the feedback of spectators, both by triggering events during the acts and generating adaptive responses and dialog. Spectator reaction is produced through a description of appropriate audience behaviors combined with a changing assortment of characters and personalities, so that identical schticks provoke varying responses from the house. A compromise was struck between allowing the audience autonomous (and potentially unmanageable) behavior and providing completely scripted, rule-based actions. This balance provides the application integrators with the ability to build appropriate group behaviors, while demonstrating sufficient anomalous individual actions to achieve believability.

Combat Modeling and Analysis

LTC Tom Cioppa, USA, TRAC-Monterey

Cognitive Task Analysis in Validating of Cognitive Models for Combat Simulations

As part of his dissertation research, Major Simon Goerger conducted two extensive experiments on the use of subject-matter experts in the evaluation of cognitive models. We have shown how we can use physical models for important uses but problems arise when we add the complexity of modeling a human operator. These problems are as prevalent in modeling vehicles as for dismounted infantry because it is difficult, if not impossible, to model the performance and decision making of a human. While advances have been made in technologies for modeling humans, we have done little to help evaluators determine how accurate a model might be in its intended use.

Major Goerger conducted a series of empirical studies to identify subject matter expert (SME) biases and their effects on consistency and accuracy of results. We used techniques derived from the cognitive task analysis literature but adapted to the assessment of human performance.

This research concludes that a SME's bias has a statistically significant effect on subjective assessment of human performance of urban combat skills. To this end, the research demonstrates how the effects of the natural biases of SMEs can be mitigated based on the scale used to assess human behavior representation (HBR) models, providing a more consistent and accurate means of validating HBR models. In doing so, it assists the DoD M&S Community by providing enhancements to face validation procedures for assessing HBR model implementations for future use in DoD legacy and developmental combat models.

World-Class Modeling (WCM)

WCM is a multi-year project to revolutionize analytical modeling capabilities through application of open standards and open sources to create a framework for model interoperability and composability. Initial proof of concept is being developed using NSS and Combat XXI simulations integrated through the NPS SimKit discrete-event simulation application-program interface (API) library.

Our tasks are to:

- Establish a software framework for composable, scalable analytical models
- Capture and consolidate previous NPS student SimKit models into an analytical toolkit
- Perform analysis of interest to N81 using the extended modeling capabilites of NSS/Combat XXI, including joint forcible entry options and an improved strike module
- Enhance FT/AT thesis model developed in 2003 to incorporate expanded functionality in the transformation framework.

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